Spatial Correlation of Optical and Electrical Signals in Electrically Stimulated Peripheral Nerves

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Abstract
The peripheral nervous system is a simplified model for the more complex neuronal structures of the central nervous system, but it can provide useful insights on the central nervous system and at the same time is more accessible to optical investigation. In this non-invasive study, we measured electrical and optical responses of the human sural nerve at various positions, spanning 28 mm across the nerve. The optical results showed that there was a consistent decrease in intensity on a time scale of tens of milliseconds and the greatest changes in intensity were observed at the positions with the strongest electrical responses. These results show that the fast optical signals are spatially consistent with the electrical response to sural nerve stimulation. Contact artifact correction techniques were explored in the median nerve with a new four source-detector pair optical probe.

Introduction
A slow hemodynamic response can be measured with near-infrared spectroscopy (NIRS) a few seconds after activation as a result of an increase in blood flow at the area of activation in the brain. A separate faster optical response has been detected 1 and associated with event related potentials about 100 ms after the brain stimulation. These fast optical signals have been studied in the brain using visual, somatosensory, and motor stimuli.

Currently, there is no consensus as to the physiological origin or robustness of the fast optical signals measured in the brain non-invasively because the fast signal is small (~0.04% intensity change) when measured through the intact scalp and skull. The peripheral nervous system provides a potentially simpler and more robust model to study fast optical signals in response to electrical stimulation of selected nerves. This study reports the spatial dependence of the optical and electrical responses associated with the electrical stimulation of the sural nerve in a human subject.

Materials and Methods
Electrical stimulator Opixplex TS, IDS Inc., Champaign, IL
- Sampling rate: 50 Hz
- Source-detector distance: 1.5 cm
- PMT: Photomultiplier Tube

Results and Discussion
- Optical data is discussed in terms of the relative change in intensity (I), defined as ΔI/I₀, where ΔI = I - I₀ and I₀ represents the average intensity during the 120 ms immediately preceding the pulse of electrical stimulation.
- Optical signal reaches a peak intensity change of ~0.2% at about 100 ms and recovers after ~300 ms. A folding average from 0 to 28 mm was applied to the optical intensity data for each 30 second trial, 45 stimulating pulses.
- Using the modified Beer-Lambert law, the intensity changes can be translated into changes in concentrations of oxyhemoglobin [HbO], deoxyhemoglobin [Hb] and total hemoglobin ([HbT] = [HbO] + [Hb]).
- Electrical recordings (Fig.4) at the 15 different positions showed electrical response at 6-14 mm. Maximum optical response recorded at 12 mm position.
- Electrical and optical data (Fig.5 & 6) suggest that the lateral spatial extent of both signals is about 8 mm. Optical data is the maximum ΔI (%) averaged from 5 trials.
- We observe a trend where the signal starts from zero at positions closest to the ankle and returns to zero at positions closest to the sole.

Conclusions
- Fast optical signals are spatially correlated with electrical signals measured in the sural nerve.
- Fast optical signals measured in the peripheral nerves are ~1 order of magnitude larger than those measured in the brain.
- Fast optical signals have been successfully measured on two peripheral nerves: sural and median.
- Contact artifacts can affect optical data and methods to quantify this effect should be further developed to minimize the influence on the physiological optical data.
- Unrecorded signals containing contact artifacts can show a variety of characteristics.
- By using the 4 source-detector pair optical probe, contact multiplicative factors can be mathematically cancelled out, leaving physiological signal of interest.
- Contact factor corrected signal represents the physiological response resulting from a combination of the 4 source-detector pairs.
- More development on this contact correction method is needed.

References

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